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Making Fiberglass Body Tubes for FAI Rockets - Part 1

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Making Fiberglass Body Tubes for FAI Rockets - Part 1

By Tim Van Milligan

The quest for the perfect body tube for competition rocketry has been a rough and expensive journey for me. The desire is an ultra-lightweight tube with a perfectly smooth finish. Plus, you want it colorful so that when the rocket lands after a three minutes drift down range, you can find it easily. And of course, you want it to be cheap and easy to manufacture. Having said that, I can tell you that I'm still a long way from realizing the dream of a perfect tube.

This article is a history of my quest to find and my attempt to make that perfect tube, however, I am still a long way away from the finish line. I'm ashamed to say this, but one thing that I'll tell you up front was that I was working in a vacuum. I didn't reach out to other modelers and ask them for their opinions and what things they tried that didn't work. Because of that, when I got to the World SpaceModeling Championships in Ukraine this past summer, I discovered that I may have gone down the wrong path from the get-go. In hindsight, in order to reduce weight, I should probably have stayed away from fiberglass and tried different plastic films.

Some of the things I tried got me a little closer to the goal of the perfect fiberglass tube, but most of the techniques and materials didn't. They were a waste of effort.

The theoretical advantage of tubes made out of fiberglass is that you can end up with a single piece tube. This helps, because the optimum shape of the rocket is not a straight tube.

In international competition, the rules dictate a rocket with a minimum length of 500mm, and a diameter of that is 40mm for at least 50% of the overall length. Weight is the big enemy in competition, so to reduce it, you want to minimize the size and amount of material. It ends up that the rocket starts out fat at the nose end and gradually necks down to the diameter of the motor at the rear. In essence, there is a transition in the middle of the rocket. With a fiberglass rocket, the shape of this transition can be molded at the same time as the straight parts of the rocket (Example in **Figure 1**). What this means is that the joints can be very smooth so as to reduce aerodynamic drag of the rocket.

Figure 1: The typical shape of a rocket used for international competition. The length is 500mm, and the maximum diameter is 40mm.

I wrote in **Peak-of-Flight Newsletter #212** (https://www.apogeerockets.com/education/downloads/Newsletter412.pdf) that I've been making fiberglass tubes since around 1990. I have never been satisfied with the quality of my finished tubes. I wasn't even getting results as good as others, like Dave O'Bryan as seen in his video at: https://www.youtube.com/watch?v=NYM1BFqA24M. I would say that this was my starting point for models. The difference was that I wasn't wrapping the tube with ¼-mil mylar, mainly because I didn't have access to any, and I was too lazy to track some down.

I was making a fiberglass tube based on molding over a male mandrel. If you want to try this yourself, you can get an aluminum mandrel at: https://blastzone.org/nar/narts/store.asp?groupid=12720058171961 (**Figure 2, Page 3**).

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Besides the heavy weight, what I didn't like about my previous tubes was the surface finish. The tubes were not glass smooth, and trying to sand them down was a nightmare. The wall thickness is so thin that it is easy to sand right through them.

Figure 2: The aluminum mandrel used for making tubes. You'll also need to make a cradle to hold it so it can be rotated when you apply the fiberglass cloth.

I had heard from a friend that some airplane modelers were stretching a rubber balloon over the laid up fiberglass. My first experiment was to give that a try. I went out the store and bought some of those long balloons that are twistable into shapes.

The process of putting a mandrel with fiberglass into a balloon involves partially blowing up the balloon and plunging the mandrel into it. Essentially, the balloon is turned inside out as it slips over the mandrel.

The result wasn't what I hope for. The straight portion of the tube was ok, but the transition didn't work well. I ended up with folds in the balloon because it didn't shrink uniformly back down around the mandrel. When the epoxy cured, it left those stretch marks in the transition as shown in **Figure 3**.

Figure 3: The stretch marks left in the surface of the tube caused by the stretching of the rubber balloon.

The orange color of the tube was accomplished by spray painting the mandrel with fluorescent paint prior to laying down the fiberglass cloth. Of course, it was sprayed on over the Crown Mold Release (wax) that was applied first. I wanted to try to see if I could make a highly visible rocket that would be easier to find after drifting for a few minutes. It definitely was very colorful.

Unfortunately, the solvents in the paint ate through the wax mold release. Because of this, the fiberglass tube (shell) was bonded to the aluminum mandrel. I had to tear the fiberglass off the mandrel to remove it.

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Figure 4 shows what the mandrel looked like after it was removed.

Figure 4: The paint that was stuck to the aluminum mandrel after the fiberglass was torn off.

It took several minutes of buffing with a pad of steel wool in order to remove the paint and buff the tube back up to a nice shine, as seen in **Figure 5**.

Since the balloon didn't work at smoothing down the surface of the transition, I went back to an experiment that I made a few years back. That was to make a silicone rubber mold of the mandrel, and then insert the mandrel back into it after the fiberglass cloth was laid on. This is the same technique I used for fiberglass nose cones, as described in **Apogee Technical Publication #12** (https://www.apogeerockets.com/Rocket_Books_Videos/Pamphlets_Reports/Tech_Pub_12). The difference here would simply be a longer mold, the length of the entire mandrel.

Figure 5: The mandrel was polished with fine steel wool to bring back the shine.

To make the mold, I got some silicone thickening agent from my silicone supplier, and then simply painted the mandrel with the liquid silicone rubber (**Figure 6**).

What I didn't like about the rubber mold, which is why I abandoned the previous experiment a few years ago, was the wall thickness of the rubber was not uniform. What I did in the past was to slice the rubber mold down one side so I could get it off the mandrel. When the fiberglass

Figure 6: The mandrel painted with silicone rubber. A thickening agent was added to slow the running of the liquid silicone.

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wrapped mandrel was put back into the mold, there would be a slit down the side. The rubber was held tight against the mandrel using a few dozen rubber bands. When the epoxy was cured, the rubber bands would be removed and the rubber shell would be peeled off.

Unfortunately this left a seam where the edges of the rubber came back together which would have to be sanded off. The other issue was that the rubber mold never went back on the mandrel in the right position, so usually the transition had problems. If the rubber doesn't lay directly against the fiberglass, air is trapped underneath and you get a really horrible surface.

Figure 7: The mandrel was encapsulated in silicone rubber and allowed to cure.

It was at this point that I remembered why I abandoned the technique a couple of years ago.

I decided to make a complete casting of the mandrel so I could get a uniform wall thickness around it. What I did was tack-glue the mandrel to a piece of plastic. Next I took a paper body tube and glued it to the plastic sheet too, with the mandrel centered in the middle. From there, it was simply a matter of pouring the silicone rubber around the mandrel (**Figure 7**) and letting it cure overnight.

Removing the mandrel out of the rubber is easy. I just peeled away the tube from the mold as shown in **Figure 8**.

Figure 8: The tube is removed by peeling it off the silicone rubber.

The next step is the hardest by far, getting the aluminum mandrel out of the hardened silicone rubber mold. Previously, I just took a hobby knife and slit the rubber along one side of the mandrel. You have to be careful not to scratch the aluminum with the hobby knife if you do this, because any scratches in the aluminum make it harder to remove the fiberglass from

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it after it cures. It is sort of like roughing up the surface to make the epoxy stick better.

Because I was hesitant at scratching the mandrel with the steel knife, I thought it might be worth a shot to try and slide the mandrel out. The problem is there isn't any portion of the mandrel exposed to grip on. Then I had an idea - the bottom of the mandrel has a threaded hole in it from the manufacturing process. I thought I could screw something into it, and use that as an aid in pulling the silicone mold off the mandrel.

I made a big washer out of plywood, and used that to tug on the rubber. You simply can't pull the rubber off the mandrel. The rubber has to be compressed, not pulled in tension.

I ended up standing on the washer and getting my fingers under the end of the silicone to put it in compression (see **Figure 9**).

It took a lot of effort, but I was able to get the rubber mold off the mandrel. It was difficult because of the surface tension holding it on. But once you break the tension, it is easy to slide it off.

The next step is to spray the mandrel with the wax mold release, and then wrap the mandrel with fiberglass cloth (**Figure 10**). I put a little extra epoxy on, and then slid it into the rubber mold. The mandrel slides surprisingly easy into the rubber mold, mainly because the liquid epoxy acts like a lubricant. Because the silicone fits snugly over the mandrel, it has to stretch a little bit to fit

Figure 9: To put the rubber into compression to pull it off the mandrel, you have to make a little tool from a large washer and a screw.

Figure 10: The fiberglass covered mandrel ready to go into the silicone tube.

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over the fiberglass covering it. This puts the rubber in tension, squeezing the mandrel a little bit, and forcing the excess epoxy to be squeegeed off as it is slid into the tube. The result is less epoxy on the tube, so you end up with a lighter weight tube.

When the epoxy had cured, the silicone rubber mold was pulled off the mandrel. The same "stand on the washer" technique used previously was also used here. It is much easier to pull out the mandrel here than it was when the silicone was virgin. It literally takes less than three seconds to pull it out of the rubber.

I was impressed at the smoothness of the straight portion of the tube. It was as smooth as the surface of the mandrel. No sanding would be necessary! And there was no need to sand off a seam like there was when I tried this previously with a split open silicone rubber wrap.

The one problem though was the transition portion of the tube. The mandrel wasn't seating tight enough against the inside of the silicone rubber mold, so there was air trapped in it. So the surface on the transition was a disaster.

Figure 11. The transition wasn't tight against the rubber in the mold, so air wasn't forced out in that area of the tube.

I tried 6 or 7 times to see if I could force the rubber tighter up against the transition. But no matter what technique I used, it would still have little pools of epoxy on the surface, like shown in **Figure 11**. It was a problem that I didn't know if I could solve.

Here is where some luck kicked in. At the same time I was working on making these large tubes, I was also working on the issue of fabricating smaller fiberglass nose cones and tubes for the altitude event, also for international competition. I was also using the same technique of shoving the nose cone mandrel back into the silicone rubber mold (**Figure 12**).

I was also playing around with some techniques for getting them colored, so that they would be easy to find. As done previously I layed the fiberglass cloth and epoxy on the mandrel. This time excess epoxy was pulled off with paper towels, and it was allowed to thicken up and get tacky.

You can't plunge the mandrel into the mold when the epoxy is still fresh and runny. If you

Figure 12: The mandrel and rubber mold that I used to create fiberglass nose cones.

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do, the fiberglass will shift on you as it goes into the rubber mold. Trust me… I ruined dozens of parts trying to figure out how to get it in without the cloth moving on me. The same problem was also happening on the big 40mm diameter tube. I found that it had to wait until the epoxy got tacky so it stuck well against the mandrel.

While it was in this tacky state, I sprayed it with fluorescent paint. Since there was already epoxy covering the mold release, the paint did not get down to the mold release. I didn't want a repeat of the failed experiment where I had to cut the fiberglass off the mandrel later.

When the paint was dry, I re-coated the mandrel with a thin layer of fresh and low viscosity epoxy, and then plunged it into the mandrel. When it goes in, the excess epoxy is squeegeed off as shown in **Figure 13**.

There was one huge difference though. If you just do what was described above, you'd have to have some luck on your side. As with the big tube, it is possible to trap air bubbles against the rubber. Air bubbles ruin the finish of the part, and they are very difficult to remove. So what did I do differently to prevent the air bubbles?

During the same time of this project, we had just modified the way we were making cast resin parts here at Apogee. Some parts, like the fins used on the Saturn V (https://www.apogeerockets.com/Rocket_Kits/Skill_Level_5_Kits/Saturn_V_1_70th_Scale) also had problem with

Figure 13: After wrapping the mandrel with fiberglass cloth, it was plunged down into the rubber mold.

air bubbles getting into the mold. I learned a trick from Matt Steele, who did a R&D report at NARAM showing how to get rid of those air bubbles. The trick was to put the mold inside a painter's pressure pot, and squeeze the bubbles down using air pressure inside the pot.

That trick worked phenomenally on the cast resin, so I wondered if it would work well for fiberglass too. It was an easy experiment to do. I just sat the silicone rubber mold inside the pressure pot overnight (**Figure 14, Page 9**) while the epoxy cured.

The pressure used was about 30 psi, and the part stayed in its silicone mold

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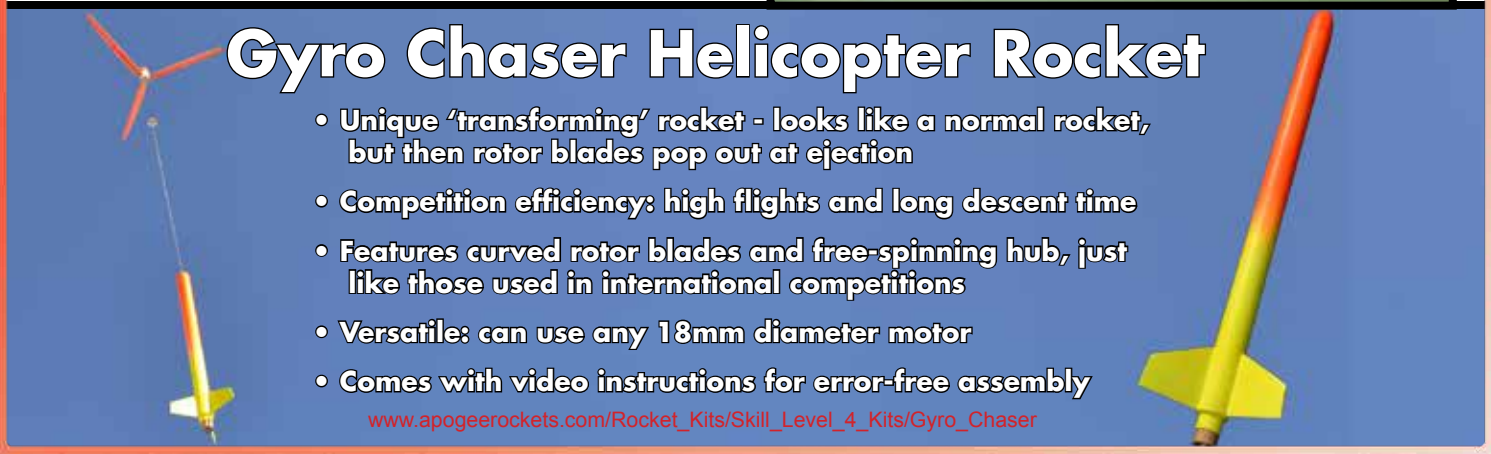

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until the epoxy was cured. The results were much better than I had anticipated. The surface was glass smooth, as seen in **Figure 15**. There would be no sanding of the surface needed. In fact, sanding would ruin it because it was so smooth.

Figure 14: The pressure pot used to squeeze the rubber nose cone mold.

In hindsight, I should have thought of this previously. I know that autoclaves are used in the manufacturing of composite parts. I just hadn't put it together that I could substitute a simple and inexpensive pressure pot for an expensive autoclave. Duh!

Figure 15: The finished part after being removed from the mold and mandrel was impressive.

The trick to getting a consistently smooth surface on the tube is to add pressure to squeeze the rubber mold against the fiberglass/epoxy on the mandrel. That's all it takes!

In the next issue, I'll pick up here and show you what I came up with to

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apply pressure to the long mandrel that makes the 40mm diameter tubes.

About The Author:

Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor, and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.apogeerockets.com) and also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at: https://www.apogeerockets.com/Contact.

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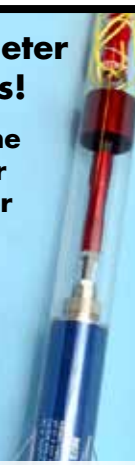

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